

DATA-INTENSIVE SCIENCE MEETS INQUIRY-DRIVEN PEDAGOGY: INTERACTIVE BIG DATA EXPLORATION, THRESHOLD CONCEPTS, AND LIMINALITY

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Identifying and Better Understanding Data Science Activities, Experiences, Challenges, and Gaps Areas



We are more easily persuaded by the reasons we ourselves discover than by those which are given to us by others."

Blaise Pascal

This poster outlines our ideas on how the combination of big data and a data exploration engine can potentially be used to change the way we teach atmospheric science

Threshold Concepts and Liminality

- Threshold concepts in any discipline are, by their very nature, troublesome, irreversible, integrative, bounded, discursive, and reconstitutive [Perkins, 1999, 2003; Cousin, 2006; Meyer and Land, 2003].
- These concepts are the deciding factors determining the extent to which the learner has mastered the core of the discipline and is prepared to work competently and creatively within it [Meyer and Land, 2006; Cousin, 2006].
- The movement of individuals from a state of ignorance of these core concepts to one of mastery occurs not along a linear path but through what Meyer and Land term liminal spaces, conceptual spaces through which learners move from the vaguest awareness of concepts to mastery, accompanied by understanding of the relevance, connectivity, and usefulness relative to questions and constructs in a given discipline [Meyer and Land, 2006].
- The challenges observed in traditional teaching exhibit characteristics typical of learners who are encountering threshold concepts but failing to move forward in mastering those concepts.
 - Specifically, lack of learner engagement, reliance on mimicry rather than mastery, and failure to demonstrate creative and critical understanding of the concepts in new applications are common.

Data Intensive Science

- Data-intensive science [Gray, 2007] represents a paradigm shift driven by large volumes of complex data that cannot be analyzed manually.
 - Scientific discovery process is driven by knowledge extracted from large volumes of data.
- Lending itself naturally to inquiry-driven pedagogy, data-intensive science privileges knowledge discovered through inductive engagement with large volumes of data rather than reached through traditional, deductive, hypothesis-driven analyses.
 - The roles of inductive, data-driven methods versus deductive, hypothesis-driven methods have been hotly debated in scientific research communities, often positioned as competitive at best and mutually exclusive at worst.
- Data- and technology-driven science can complement and be complemented by hypothesis-driven science in ways that can inform the development of best practice not only in research but also in education [Kell and Oliver, 2004]
- Data intensive methods *can allow for exploration on a scale that is not possible in the traditional classroom* with its typical problem sets and static, limited data samples.

Missing Component: Discovery Engines

- A key challenge in data-intensive science is the development of enabling technologies to render tremendous volumes of a wide variety of data accessible in both the lab and the classroom.
- *New “discovery engines” are needed to allow users to move beyond meta-data queries to **explore** large volumes and time series of multidimensional data—to discover promising nuggets of information, and to select and extract those nuggets for rigorous analyses.*
 - These discovery engines can facilitate an interactive discovery process whereby users can refine their queries and drill down into the data based on their own emerging, contextualized, scientific curiosity.
 - The processes inherent in this exploring, mining, analysis, and discovery resonate with the engagement of learners with threshold concepts.
- *As a result, these discovery engines enable the use of big data as a source through which to encourage learner engagement with and mastery of threshold concepts.*

Grand Vision

- Our proposed idea frames big data as a conceptual playground and the discovery engines as a key tool
- Founded on principles of inductive, experiential learning, our approach incorporates an iterative approach to problem solving that involves initial engagement with big data reflecting real-world situations through which learners come to identify relevant or promising patterns.
- These patterns, in turn, can be compared against additional real-world situations and contexts, thus allowing learners to follow a grounded approach to learning and knowledge creation through observation, formulation of hypotheses, and constant comparison of data across various real-world situations.
- Learners are given the opportunity to work through increasingly unstructured data driven challenges with access to relatively infinite iterations of problems through which they come to understand the targeted concepts.
- Students learn to add concern for fit, relevance, workability and modifiability of any generated theories to their already honed abilities to assess validity of claims from a traditional scientific perspective.

Developing Critical Thought Processes Using Data Driven Exploration: An Example

- Cold water ocean regions may be triggered by intense vertical mixing of the ocean, a phenomenon referred to as ocean upwelling. Figure 1a shows three such cold regions in the Cross-Calibrated, Multi-Platform (CCMP) Optimally Interpolated Sea Surface Temperature (OISST) data on March 27, 2008.
- Students can be asked to explain what is causing this phenomenon. Students will be nudged to develop critical thought processes using the theoretical framework to develop different hypotheses, and to use, a discovery engine (Polaris – prototype used here), on several years' worth of satellite observations to test their hypotheses.
- In this example, when atmospheric conditions are right, a pressure system causes a low-level wind jet through gaps in coastal mountains and over the ocean, leading to intense ocean mixing.
- This can be confirmed by running simple threshold queries on the data exploring the sea surface temperature and surface wind for the same regions. Discover engine provides both a visual confirmation of such events (Figure 1b) and gives climatological information.
- *We envision that in the future, exploratory exercises like this will be used in the classroom to help the students develop critical thought processes required not only linking concepts in the theoretical framework with observed phenomena but also gaining a firm grasp on the research methodology*

Processes Using Data Driven Exploration: An Example

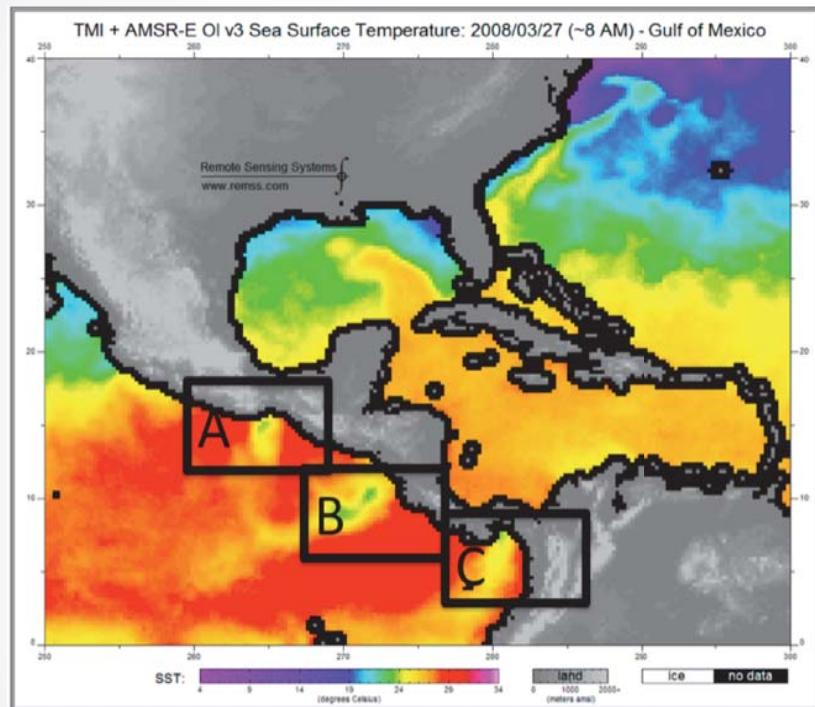


Figure 1a. OISST data coverage for three Central American sites on March 27, 2008 that shows a drop in sea surface temperature.

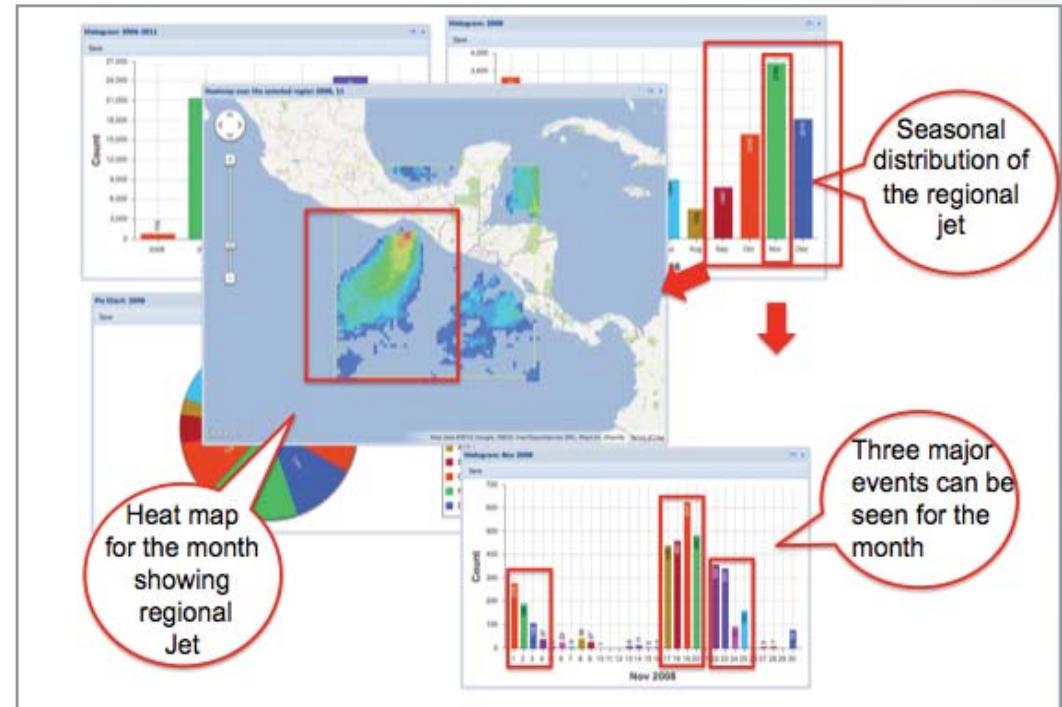


Figure 1b. Polaris query results “discovers” regional wind jet causing the ocean upwelling. Results allow additional insights about the regional jet such as seasonal distribution, how long these events last.

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